Watershed Monitoring for the Northwest Forest Plan

Data Summary Interpretation 2005
Franciscan Province

Prepared By:

Aquatic and Riparian Effectiveness Monitoring Program Staff

USDA Forest Service, Pacific Northwest Regional Office
Bureau of Land Management, Oregon State Office

4077 S.W. Research Way, Corvallis, OR 97333
http://www.reo.gov/monitoring/watershed

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INTRODUCTION

The Aquatic and Riparian Effectiveness Monitoring Program (AREMP or the monitoring program) is a multi-federal agency program designed to assess the effectiveness of the Northwest Forest Plan's Aquatic Conservation Strategy (USDA, USDI 1994) in maintaining or restoring the condition of watersheds in the Plan area. To evaluate the effectiveness of the strategy, the monitoring program determines whether key processes that maintain aquatic and riparian habitats are intact (Reeves et al. 2004). This information is used to assess the current condition of watersheds and to monitor changes in condition through time.

The Northwest Forest Plan was designed to account for the complex and dynamic nature of aquatic ecosystems resulting from the wide range of physical characteristics, natural disturbance events, and climatic features of the region (Benda et al. 1998, Naiman et al. 1992). Consequently, the assumptions underlying the monitoring program are that watersheds are dynamic systems that will not remain in a static condition indefinitely. Nor do we expect all watersheds to be in good condition at any one time (Naiman et al. 1992, Reeves et al. 1995). The primary product of the monitoring program is a distribution that describes the range of conditions of watersheds in the Plan area. Implementing the strategy should result in a range of watersheds conditions across the landscape that represents the natural range of conditions expected in a well-functioning aquatic network. If the strategy is effective, then the overall condition of watersheds across the region should either remain the same as it was when the strategy was implemented in 1994, or it should improve.

Watershed condition is evaluated at the USGS 6th-field hydrologic unit subwatershed (hereafter referred to as watershed) scale using a province-specific decision support model that aggregates data on in-channel, riparian and upslope attributes. These attributes are indicators of watershed processes. A watershed is defined as being in "good" condition if the physical attributes are adequate to maintain or improve biological integrity, with a focus on diversity and abundance of native aquatic and riparian-dependent species, salmonids in particular.

The purpose of this report is to provide local units with the results of our data collection and decision support modeling efforts for watersheds surveyed in the Franciscan physiographic province (Table 1). Separate reports were prepared for each physiographic province. Included in this report are overviews of field (in-channel) data collection methods and calculations performed on the data, GIS data collection methods, the decision support model used to evaluate watershed condition, and a guide on how to interpret the model results. Watershed-specific summary tables, maps, photos, raw field data files and GIS data accompany this report on the AREMP website. Benthic macroinvertebrate and periphyton samples were collected in the field. These samples from some of the watersheds are currently at the laboratory being analyzed and were not available to be included in this report or the model output. Links to additional documents pertaining to the monitoring program and decision support models are available on the website.

New in 2005

This year, we completed a 10-year assessment of the Northwest Forest Plan's Aquatic Conservation Strategy. In this assessment, we compared the condition of 250 randomly selected 6th-field watersheds in 1994 with their current condition. This report is available electronically

Table 1. Watersheds sampled in the Franciscan Province 2002-2005.

USGS HUC	Watershed Name	Administrative Unit
171003120106	BOULDER CREEK	SISKIYOU NF
171003100602	SHASTA COSTA CREEK	SISKIYOU NF
180101050201	NORTH FORK EEL RIVER	SIX RIVERS NF

at: www.fs.fed.us/pnw/publications/pnw_gtr647/ or in hard copy through the USDA Forest Service Pacific Northwest Research Laboratory.

Assessing watershed condition consisted of aggregating road, vegetation, and in-channel data using a decision support model. Watershed monitoring for the Plan has only been conducted since 2002; consequently, in-channel data were available for only 55 of the 250 randomly selected watersheds. Road and vegetation data, which were available for all 250 randomly selected watersheds at 2 time periods, were used to examine trends.

The distributions of conditions were presented for watersheds in the Plan area and for many of the attributes that contribute to the condition of watersheds by land use allocation. Under the Plan, management activities were implemented in a way to promote positive changes in the condition of watersheds. This assessment revealed that the net growth rate of trees (2 to 4 percent) exceeded losses (1.6 percent owing to stand-replacing fire and harvest), and nine times more roads were decommissioned than were constructed. Fifty-seven percent of the watersheds had higher condition scores in time 2 (1998-2003) than in time 1 (1990-96) across the entire Plan area. Only 3 percent of the watersheds had lower condition scores in time 2, and the scores did not change in the remainder of the watersheds. The watersheds that decreased in condition were all exposed to wildfire. More key watersheds, which were given the highest priority for restoration activities, increased in condition than non-key watersheds (Gallo et al. 2005).

AREMP also participated in a field protocol test sponsored by the Pacific Northwest Aquatic Monitoring Partnership watershed workgroup. A side-by-side protocol comparison test for in-channel physical attributes was conducted in the John Day Basin, OR during summer 2005. Ten different tribal, state, and federal agencies - including AREMP field crews - participated. The goal of the proposed side-by-side protocol comparison test is to determine the best protocols for assessing a common set of in-channel stream attributes. The data from the test are currently being analyzed. Results will be released summer 2006.

METHODS

Study Design

Monitoring is conducted in 250 randomly selected 6th field watersheds, each approximately 10,000-40,000 acres in size (Figure 1). To be included in the sample, a watershed must contain a minimum 25% federal ownership along the stream, based on the 1:100,000 stream layer. The program's goal is to monitor 50 watersheds each year on a five-year rotation (Reeves et al. 2004).

However, the program has yet to be fully funded, therefore we have sampled only 100 watersheds from 2002-2005. Data were collected for in-channel, riparian, and upslope attributes. In-channel attributes were collected at randomly-selected sites (6 sites on average) within each watershed. Upslope and riparian data were collected from vegetation and roads layers using GIS. The evaluation of upslope and riparian conditions in watersheds was tailored to specific physiographic provinces. The physiographic boundaries used in this analysis were developed from those used in the aquatic ecosystem assessment, which were based on broadly drawn precipitation and geologic areas (FEMAT 1993).

Field Data Collection

Field data provide information on the physical habitat and the biota. Physical habitat indicators include: bankfull width to depth ratio, entrenchment ratio, pool frequency, sinuosity, gradient, wood frequency, percent pool-tail fines, and substrate D_{50}. Water chemistry data were also collected. Biological indicators include: periphyton, benthic macroinvertebrates, aquatic and terrestrial amphibians, and fish.

Three types of surveys are conducted, with each type referring to a different point in time and a different purpose for the data collected. However, the data collection protocols were the same for all survey types. The survey types (with definitions) are as follows:

- Initial Surveys – These surveys were conducted at sites that the monitoring program had not previously surveyed. The sites were surveyed within a subset of the 250 randomly selected watersheds used to assess the success of the Northwest Forest Plan.
- Quality Assurance/Quality Control (QAQC) Surveys – These surveys were conducted at sites that were randomly selected from the initial surveys. The intent of these surveys was to determine the abilities of field crews to measure the same segment of a stream consistently. These surveys always occurred after the Initial Survey and were conducted by an independent crew. During the resample visit, only the start point of the survey was established. All other sampling was conducted in the same way as the original survey.
- Trend Surveys – These surveys were conducted at the previous year's QAQC sites. These sites were surveyed by a different field crew at each subsequent survey. The intent of these surveys is to assess trend in a subset of the 250 watersheds prior to completion of the full cycle of sampling. Results of the trend analysis will not be presented here, but will be available on our web site when it becomes available.

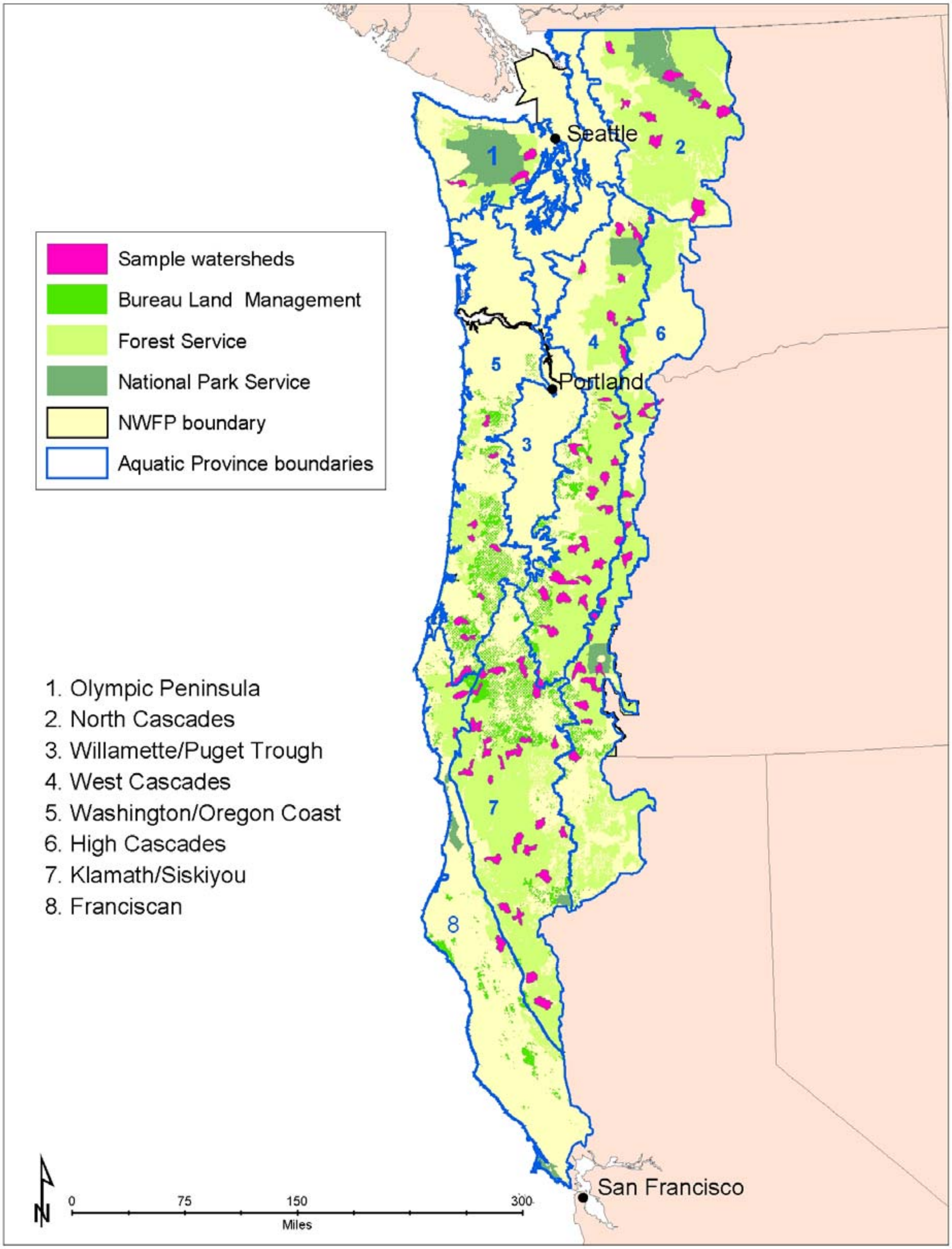


Figure 1. Randomly selected watersheds sampled 2002-2005 by the aquatic and riparian effectiveness monitoring program.

For the initial surveys, eighty potential sampling sites were randomly chosen along the stream network in each watershed and identified with a GPS coordinate. In the field, sites were considered for sampling in numerical order, omitting sites that could not be sampled. The goal was to sample as many sites as possible within the watershed. However, because of logistical constraints, we usually sampled the first six to eight accessible sites. Typically, fewer sites were sampled in watersheds that required a lot of time traveling to remote locations. The only reasons that a site was not sampled was if it was located on private land or could not be accessed due to private land; it was located on a glacier or in a lake; it was not safely accessible; if more than 25 % of the stream channel was dry; the stream was too small to sample (less than 1 meter wetted width and 0.1 meters deep in riffle habitats); the stream was too large to physically sample (pools were too deep to wade, picking up pebbles on the bottom would require a wet suit, and wading across the stream was only possible in a few riffles); or travel time on foot to and from the site was greater than 4 hours.

The length of each site was approximately 20 times the bankfull width (using 2 m bankfull width categories) with minimum and maximum reach lengths of 160 and 480 m. Sampling was conducted at 21 transects (11 major and 10 intermediate transects), equally-spaced along the length of the sample reach (Figure 2). We established the start point for sampling at the GPS coordinate and measured the reach upstream along the thalweg one transect at a time. The end point was established at the 21st transect location. Side channels were included in the survey only if they began and ended within the survey reach and the average bankfull width of the side channel was at least 20% of the bankfull width of the primary channel. We documented the start of the reach by recording the GPS coordinate with a Garmin GPS 12-map, taking a minimum of four photos from the start point (facing left bank, downstream, right bank and upstream), and posting a marker near the start point. Photographs of the sample location and unique features were used in lieu of monuments in wilderness areas.

Physical Habitat

Bankfull widths, valley length, bed elevations and one cross-sectional profile were measured in each sample site using a laser rangefinder. We measured bankfull width at each of the eleven major transects and calculated average bankfull width of the reach based on these measurements (Table 2). Additional points were measured at the wetted edges and thalweg of major transects and at the thalweg of minor transects. Sinuosity was calculated as the length of the reach along the thalweg measured with a measuring tape, divided by the straight line distance between the thalweg at the start of the reach to the thalweg at the end of the reach, measured with the laser. Reach gradient was determined by the change in elevation of the left wetted edge at the bottom (transect A) to the top (transect K) of the reach, divided by the reach length.

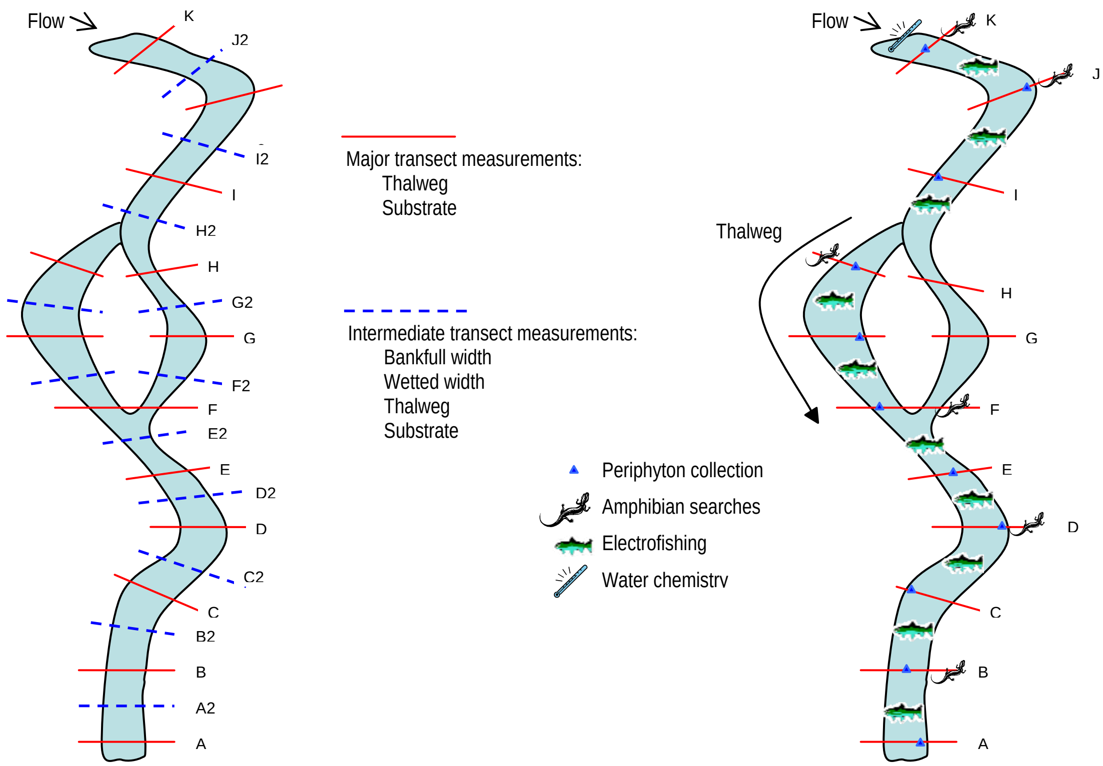


Figure 2. Overview of site layout and sampling strategy. The start point is established at the downstream end of the reach at transect A. Major and minor transects are equally spaced along the thalweg. Measurements and sampling conducted at each transect is outlined in the figure.

At each reach, data from one channel cross-section extending beyond the flood prone elevation were used to calculate bankfull width to depth ratio and entrenchment ratio. The cross-section was located at the first inflection point of the first riffle encountered, where the channel was relatively straight and did not have secondary channels, human or animal crossings, deflectors or unusual constrictions that narrow the channel or create exceptionally wide backwater conditions. We defined the floodprone height as two times the maximum bankfull elevation, and the floodprone width as the perpendicular distance between the floodprone constraints. At the cross-section, eleven equally-spaced depth measurements were taken on increment, within and perpendicular to the bankfull channel constraints (Figure 3). Additional measurements were taken at both wetted edges and the thalweg. Upslope of the bankfull elevation, measurements were taken to capture significant slope changes and the floodprone constraints. The bankfull width at the cross section was divided by the flood prone width to determine the entrenchment ratio for the reach (Table 2).

The locations of each pool-tail crest, maximum pool depth and pool head were captured with the laser rangefinder. Pools were defined as being concave in profile laterally and longitudinally; bound by a head and a tail crest; occupies greater than 90% of the wetted channel width at any location within the pool; has length greater than its width; maximum depth at least 1.5 times the pool tail depth; and only including pools containing the thalweg. Pool measurements were used to calculate pool frequency and residual pool depths (Table 2). Residual pool depth is the elevation change from the thalweg at the pool tail crest to the deepest part of the pool.

Substrate particles for the D_{16}, D_{50} and D_{84} calculations were measured using a modification of the Environmental Protection Agency's Environmental Monitoring and Assessment Program substrate protocol (Peck et al. 1999). Five substrate particles were collected from each of the 21 transects at 10%, 30%, 50%, 70% and 90% of the distance across the bankfull channel. Each particle was measured along its intermediate axis with a meter stick. Percent fines (particles less than 2 mm diameter) were measured in the tails of scour pools as described by the USDA Forest Service Region 5 SCI protocol (1998). A 14 inch by 14 inch Klamath grid with 7 equally spaced horizontal and vertical partitions was used to count the number of intersections on top of substrate less than 2 mm. Three grid measurements were taken in each pool tail at 25%, 50% and 75% of the distance across the wetted width, and 10% or one meter (whichever was less) of the pool length upstream of the pool tail crest. These measurements were converted to a percent and then averaged for the first 10 pools (Table 2).

The large wood protocol was adapted from the Oregon Department of Fish and Wildlife's Stream Habitat Surveys (Moore et al. 1999). Within each reach, pieces of large wood were counted if they had a minimum length of 3 m, and were at least 0.3 m in diameter at one third of the distance from the large end. Length and diameter were visually estimated for each piece. The length and diameter of the first 10 pieces encountered in the reach and every 5th piece thereafter was measured using a measuring tape so that estimates could be corrected. In addition, notes were made on the location of the wood relative to the channel, whether the piece was natural or artificial (part of a man-made structure), whether the piece was single, part of an accumulation (2-4 pieces touching) or part of a jam (5 or more pieces), and the percent of each piece of wood that would be submerged at bankfull flows.

Temperature, dissolved oxygen, pH, conductivity, and specific conductance measurements were collected at the upstream end of each sample site using a YSI 556 multi-probe meter, at five minute intervals for two hours. These measurements were averaged for each reach. Water temperature measurements were recorded hourly from June 1 until September 15 with continuous recording temperature loggers at the lowest point in the watershed on federal land. From these temperature data, the maximum seven-day average temperature was calculated.

Table 2. Equations used to calculate physical channel attributes. Precision is the number of significant digits used in the calculation.

ATTRIBUTE	DEFINITION	EQUATION	PRECISION	# OF MEASUREMENTS
Average Bankfull Width	Average of the bankfull widths measured at the eleven major transects in the reach.	(Sum of BF widths) / Number of transects	0.1 m	11
Bankfull Width: Depth Ratio	Ratio of bankfull width to bankfull depth at one channel cross-section.	Depth: Area of cross-section / BF width Width: BF width W:D = BF width / BF depth	1	1 width, 10 depth
Entrenchment Ratio	Floodprone width divided by bankfull width, measured at one channel cross section.	Floodprone width / Bankfull width	0.1	1
Sinuosity	Reach length (measured along thalweg) divided by straight valley length (length from bottom to top of reach).	Reach Length / Valley length	0.1	1
Reach Gradient (% Slope)	Elevation change of substrate surface at the thalweg, from bottom to the top of the reach divided by the reach length (measured along the thalweg).	(Change in Elevation / Reach Length) * 100	0.1 %	1
Average Residual Pool Depth	Average of residual pool depths for all pools.	(Sum of (Pool Max Depth - Pool Tail Depth)) / Number of Pools	0.01 m	All qualifying pools, according to the AREMP protocol.
Pool Frequency	Number of pools per 100 m.	(# pools / reach length) * 100	0.001 m^{-1}	All qualifying pools, according to the AREMP protocol.
Large Wood Frequency	Number of wood pieces greater than .3 m diameter and 3 m long, per 100 m.	(# pieces / reach length) * 100	0.001 m^{-1}	All qualifying pieces, according to the AREMP protocol.
Percent PTC Fines	Percent surface fines measured 3 times, 10% or 1 m upstream of the tail crest of a pool.	Average of: (Sum of # Fines Measurements / (150-(sum of # non-measurements))) * 100	0.1 %	The first 10 qualifying pools, according to the AREMP protocol
D50 Pebble Count	D_{50} (mm) is the 50th percentile (median distribution) of the substrate particles measured.	Intermediate axis diameter of the median particle collected from particle counts.	1 mm	5 particles per transect on 21 transects.
D84 Pebble Count	D_{84} (mm) is the 84th percentile. 84% of the substrate particles measured are less than the size calculated.	Intermediate axis diameter of the particle for which 84% of the particles are smaller (84th percentile).	1 mm	5 particles per transect on 21 transects.
D16 Pebble Count	D_{16} (mm) is the 16th percentile. 16% of the substrate particles measured are less than the size calculated.	Intermediate axis diameter of the particle for which 16% of the particles are smaller (16th percentile).	1 mm	5 particles per transect on 21 transects.

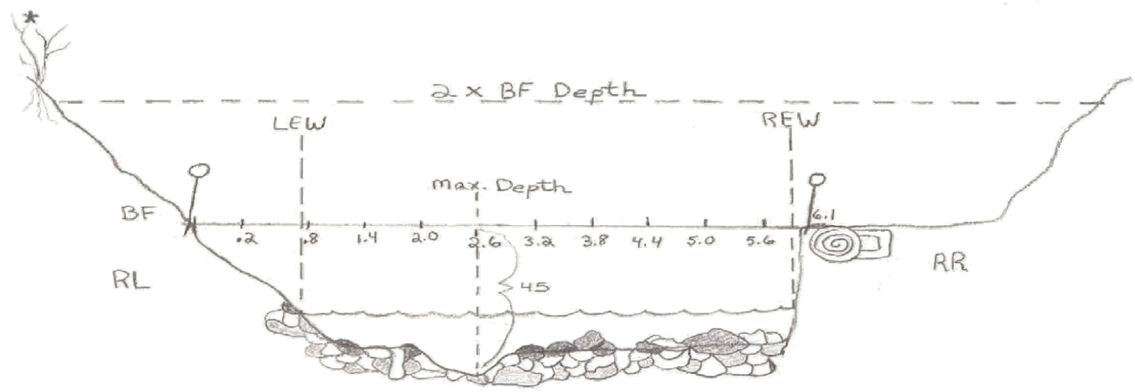


Figure 3. Example cross sectional profile with point labeling (looking downstream).

Biological Sampling

The periphyton protocol used for field collection and lab analysis is the same as that outlined by Peck et al. (1999). At each of the eleven major transects, periphyton was removed from an assigned sampling location (left, center, or right bank), which alternated at each transect. All attached periphyton inside a 12 cm^2 area was removed by scrubbing for approximately 30-45 seconds with a toothbrush. Material clinging to the toothbrush was washed into a 125 ml bottle. One subsample from each transect was composited into a single sample for each reach. Samples were analyzed by Loren Bahls, Ph.D. in Helena, MT. Each sample was placed on a slide and at least 300 individuals were identified and enumerated for relative abundance assessments. All non-diatom taxa were identified to genus; diatoms were identified to species level.

Benthic macroinvertebrates were collected and analyzed using the protocol described by Hawkins et al. (2001). Using a kick net, we collected two subsamples at randomly-selected locations in each of the first four fast-water units encountered in each reach (8 subsamples total). All rocks larger than a golf ball within each 0.09 m^2 sample area were rubbed to remove attached organisms, and then placed outside the sampling area. The exposed areas of embedded rocks were also rubbed. After all rocks were rubbed to dislodge attached organisms, the substrate within the sampling area was disturbed for approximately 30 seconds. The eight subsamples were decanted with a sieve, washbasin, and bucket to remove inorganic substrates, and invertebrates were composited into a single sample for each reach. Samples were sent to the Bureau of Land Management's National Aquatic Monitoring Center Buglab in Logan, Utah where all insects were identified to the genus level (except Chironomidae, which were identified to subfamily).

At each site, fish and aquatic amphibians were sampled using a single pass with an electrofisher. The goal was to obtain a complete taxa list and species composition for each site within the watershed. All captured animals were identified and enumerated. Animals that were missed were also noted, however the information was not used in the analysis. Animals collected from 20% of the length of the reach were measured, and their condition was estimated using volumetric displacement. Snout-vent lengths were measured for all aquatic amphibians and fork length for each fish captured.

Time and area-constrained searches were conducted for terrestrial amphibians at each site within the watershed. At six of the major transects, searches began at the wetted edge and continued up the bank on either side of the stream, within 2 m of the wetted edge. Each search lasted five minutes (ten minutes total at each transect). During this time, searchers rolled over rocks and logs, and dug through leaves and soil. All captured terrestrial amphibians were identified, counted, measured for snout-vent length, and then returned to the area captured. The protocol used was adopted from Aquatic/Land Interaction Team at the PNW-FSL (Dede Olson, personal communication).

GIS Data Collection

Analyses of road and vegetation attributes were based on geographic information system (GIS) coverages. These analyses were tailored to physiographic provinces, which were based on broadly drawn precipitation and geologic areas (FEMAT 1993). Watershed boundaries used in the analysis were from the first draft of the 6th-field Hydrologic Unit Code boundaries developed in 2002. We used 1:24,000 densified stream layers from the Forest Service Region 6 Hydrography framework project. In the Franciscan Province, we defined the riparian area by creating a 50-meter fixed buffer along both sides of all streams on the 1:24,000 stream layer.

Road Analysis

Road density and frequency of road-stream crossings were calculated using GIS coverages that were pieced together from Forest Service road and BLM ground transportation coverages. The Forest Service coverages, dated 2002, were obtained from each of the national forests in the Forest Plan area and clipped to the administrative boundaries of the forests. The BLM ground transportation coverage contains data from 1998 that cover all of the BLM districts and other non-BLM lands.

In the Franciscan Province, road densities in riparian areas were calculated for each watershed. The road layer was laid over the 50 m riparian buffer and riparian road density was calculated by dividing the miles of road within the riparian boundaries by the total stream miles. We overlaid road and 1:24,000 stream layers in each watershed and counted the number of road and stream intersections. Crossing frequency was expressed as the number of crossings per mile of stream. Forty-eight sample watersheds spread across the Plan area were inspected for potential erroneous crossings from digitizing errors. The percentage of suspected false crossings was less than two percent for the total sample.

Vegetation Analysis

The percentage of the watershed covered by urban or agricultural land, and conifer size and percentage of canopy cover in riparian areas were included in the monitoring plan's evaluation of watershed condition. Vegetation data were collected from coverages developed by the Interagency Vegetation Mapping Project version 3.0 that were updated using the vegetation change layer developed for the Northwest Forest Plan vegetation monitoring program (Moeur et al. 2005). These layers were built using Landsat Thematic Mapper remote sensing data. The coverages were clipped to watershed boundaries and the area covered by urban or agricultural land was calculated as a percentage of the total watershed area. The 50-m riparian buffer was used to calculate the percentage of forested riparian area containing conifers with diameter at breast height greater than 20 inches. To calculate forested riparian area, we subtracted non-forested areas, defined as areas incapable of producing trees (such as glaciers, lakes, lava beds or agricultural lands), from the total area within the riparian buffer.

Assessment of Watershed Condition

Decision support models were used to assess the condition of individual watersheds. These models are computer-based models that capture evaluation procedures and apply a consistent decision or evaluation process across time and space. Reeves et al. (2004) recommended using these models because they are transparent and easy to replicate. The transparent quality of the model facilitates explaining how the assessment was conducted.

Decision support models use data to evaluate a premise. For this analysis, we evaluate the premise that watersheds are in good condition. Data used in the assessment lend varying levels of support to that premise, ranging from full support to no support. We developed criteria to evaluate each attribute based on data and professional judgment. Data on individual attributes were compared to these criteria and given an evaluation score that ranges between +1 and –1, where +1 indicates full support and –1 indicates no support for the premise. Evaluation scores for the attributes were aggregated into an overall assessment of watershed condition. User-defined rules produce an aggregated score weighted toward the resource with either the highest or lowest evaluation score, or a score can be based on the weighted or unweighted average of the indicator evaluation scores. Selection of the rules was based on professional judgment that relied on knowledge of the watersheds and ecological processes. In the models used in this analysis, evaluation scores were typically aggregated using either a weighted or unweighted average. Weights were assigned based on the experts' opinions about the relative importance of individual attributes in contributing to the condition of watersheds. In a few cases, an aggregated score weighted toward the lowest evaluation score was used to allow a single variable to override other variables.

A decision support model was built, refined, and peer-reviewed for each physiographic province to account for the ecological differences that exist between provinces. The workshops consisted of an informal group process through which local experts came to consensus on the model structure and evaluation criteria. After the workshops, models were built and run and the results were returned to the workshop participants. Participants compared the results of the model to their knowledge of the condition of the watersheds and suggested refinements to the model as necessary. Changes were made to the model and the results were re-evaluated.

MODEL DESCRIPTION AND INTERPRETATION

Watershed and reach condition scores are presented in the model output table in the watershed data summary document. These scores were calculated by evaluating individual attributes and then aggregating their evaluation scores.

How the Model Works

The Franciscan Province model includes an evaluation of both watershed and reach-scale attributes. The model hierarchically aggregates data from a number of attributes into broader indices of reach and watershed condition. For example, the reach condition score also serves as one component of the broader watershed condition score. In this case, the reach condition score used in the watershed model is the average of the evaluation scores of all the reaches in the watershed. A graphical depiction of the model structure for the Franciscan Province is presented in Figures 5 and 6. In this iteration, some model sections were "turned off" because the corresponding data were not available. These unused portions of the models are indicated in gray on the diagram.

The model begins by reading a set of data observations, which we call "attributes" for a watershed. These attributes are the right-most nodes in the model structure diagrams. For example, water temperature (maximum seven-day average) is an attribute of the watershed condition model. When the provincial experts constructed the model structure, they also developed evaluation criteria for each attribute. The attributes and evaluation criteria that make up the watershed and reach condition models are described in Tables 3 and 4.

The watershed model attributes column contains the attribute name, units of measure and qualifiers, if there are any. For example, temperature is evaluated differently in watersheds depending on whether or not bull trout are present. The data value and evaluation score columns show how the data values correspond to evaluated scores. The curve shape column gives a graphical depiction of the relationship, with data values represented on the x-axis and corresponding evaluation scores on the y-axis (Table 3). The evaluation curves depict how each data value is scored on a scale from +1 to -1, according to its contribution toward overall watershed condition. As attribute data are read into the model, they are compared to the evaluation criteria to produce an evaluation score between +1 and -1. The source column gives the basis on which the curve was constructed, which is most often the professional judgment of workshop participants, but also includes datasets, published reports or standards.

For example, in the Franciscan Province, if there are no roads within the riparian area (riparian road density = 0), then the evaluation score would be +1 because it is at or less than the node-x value of 0; if road density was 0.1 miles of road per mile of stream or greater, the score would be -1; and if the density falls between 0 and 0.1, the attribute receives a score that is a linear interpolation between +1 and -1 (for example .05 would evaluate to 0). Note that there is an important difference between a data value of "zero" and "no data". Data values of zero (as in the lower-slope road density example above) are compared to their evaluation curve in the same way as all other data values.

After each attribute datum is evaluated, the model aggregates the attribute evaluation scores together in a hierarchical fashion. The combined score is passed up to the next level in the model hierarchy where it is combined with results from other parts of the model (Figure 5). To assign levels of importance to different variables, the model uses two different operators to aggregate the evaluation scores: MIN, where it takes the minimum score from those being aggregated, and AVE, where it averages the scores. These functions reflect whether the attribute is a "limiting factor" type and the worst condition score determines the combined score (MIN), or a "partially compensatory" situation, where scores are all counted equally

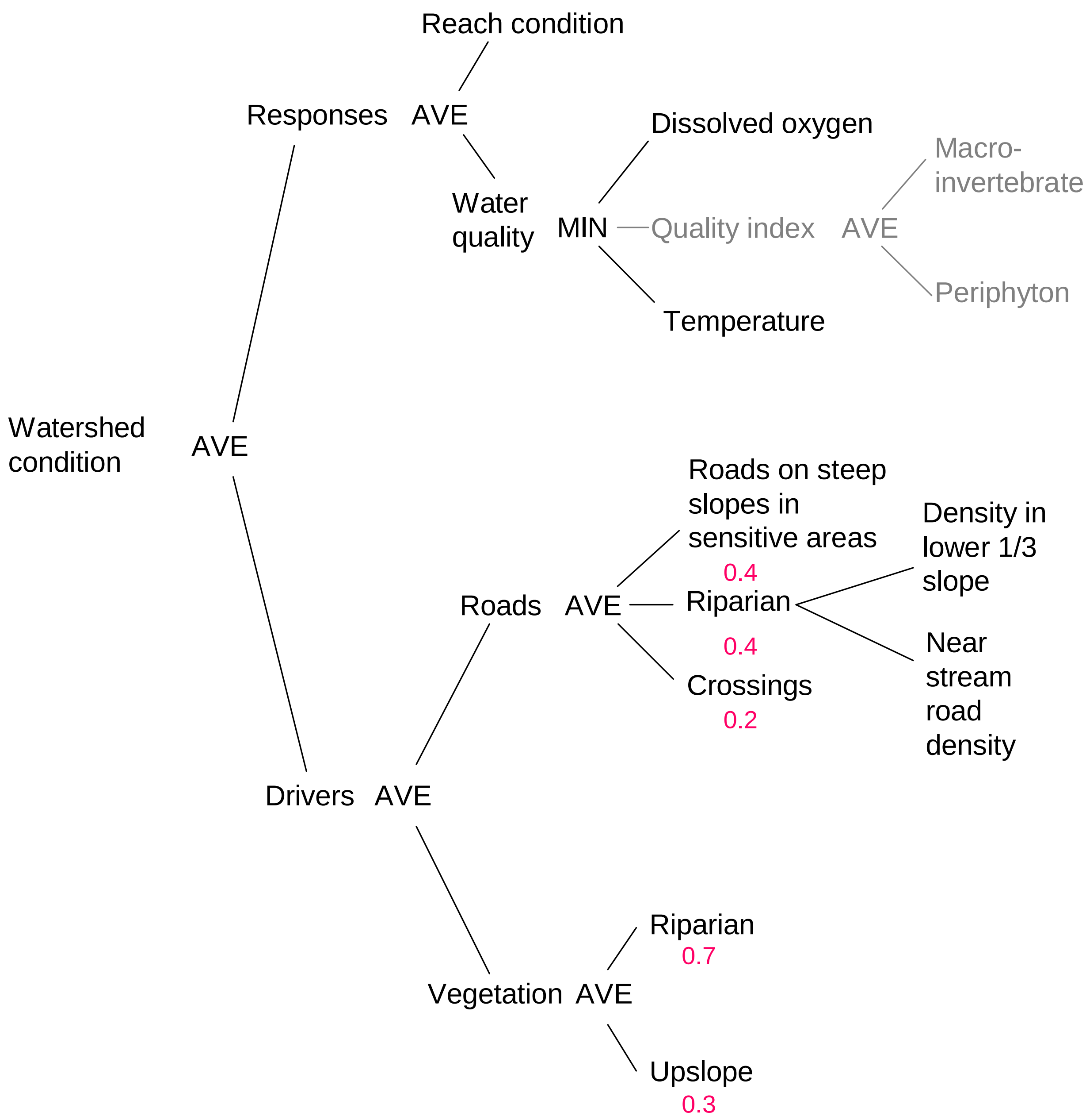


Figure 5. Graphical depiction of the watershed model structure for the Franciscan Province. The right-most nodes in the diagram represent watershed attributes that are evaluated and given an evaluation score. Evaluation scores are aggregated using the operators and weights depicted on the diagram to calculate an overall watershed condition score.

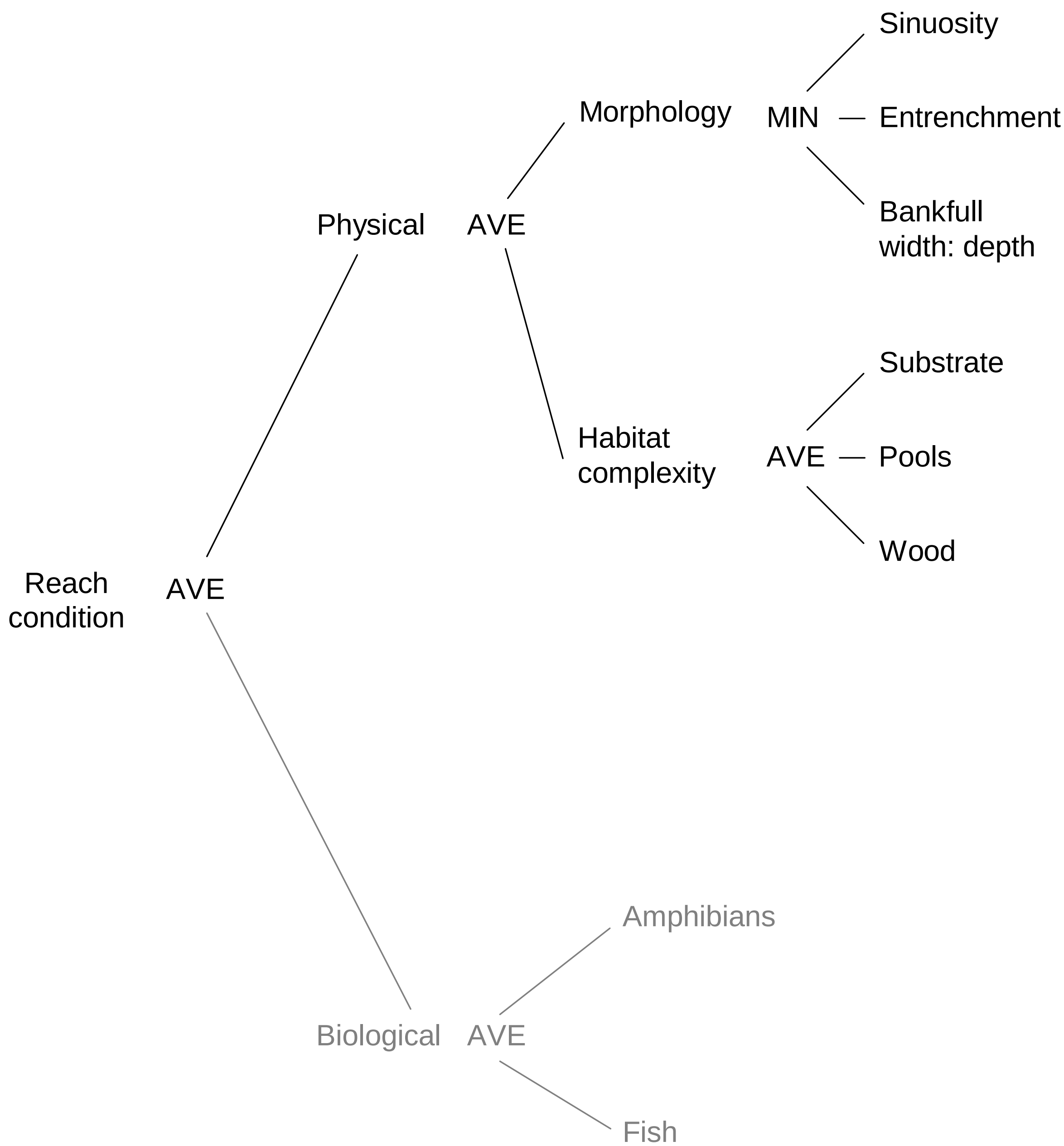


Figure 6. Graphical depiction of the reach model structure for the Franciscan Province. The right-most nodes in the diagram represent reach attributes that are evaluated and given an evaluation score. Evaluation scores are aggregated using the operators and weights depicted on the diagram to calculate an overall watershed condition score. Reach condition scores are an attribute of the watershed condition model.

Table 3. Watershed model attributes and evaluation criteria for the Franciscan Province.

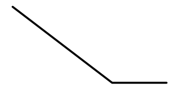
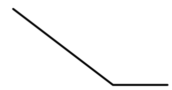
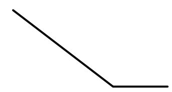
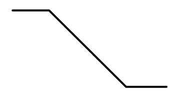
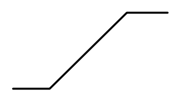
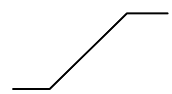
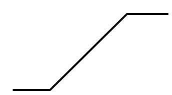
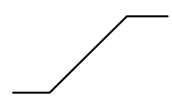
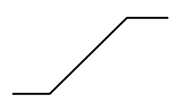
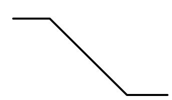
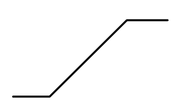
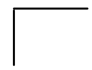
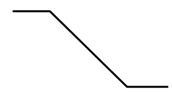
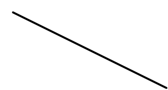
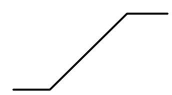
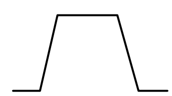
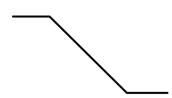
Watershed attributes	Data value Node x-value	Evaluation score Node y-value	Curve shape	Source
Road density in hazard areas mi road / mi² hazard area slope > 65% and geology sensitive to mass failure	0.5 1.5	1 -1		R Frick data
Road density in lower 1/3 of slope mi road / mi² lower slope	1 1.7	1 -1		Klamath NF data
Riparian road density mi road / mi² riparian area 50m buffer	0.5 1.5	1 -1		Klamath NF data
Road crossing frequency # crossings / mi stream	1 3	1 -1		R Frick data
Upslope vegetation Average % canopy cover coniferous forest	50 70 85	-1 0 1		Professional judgment
oak woodland	10 40	-1 1		Professional judgment
Upslope vegetation Small conifer cover % area with conifers ≤ 5" dbh wet=precip >40" dry=precip <40"	25 5	-1 1		Professional judgment
Riparian vegetation Average % canopy cover 50m buffer	50 70 85	-1 0 1		Professional judgment
Riparian vegetation Large conifer cover % area with conifers ≥ 20" dbh 50m buffer	40 75	-1 1		Professional judgment
Water temperature maximum 7-day average °C	64 68 70 75	1 0.8 0 -1		Professional judgment
Dissolved oxygen mg/L	4 7	-1 1		Professional judgment

Table 4. Reach model attributes and evaluation criteria for the Franciscan Province.

Reach model attributes	Data value Node x-value	Evaluation score Node y-value	Curve shape	Source
Entrenchment ratio slope < 4%	<2.2 >2.2	0 1		Professional judgment
Sinuosity slope < 2% entrenchment > 1.4	<1.5 >1.5	0 -1		Professional judgment
Bankfull width: depth slope < 4%	15 35	1 -1		R. Frick data
Pool frequency # wetted widths per pool	10 14	1 -1		R. Frick data
Wood frequency # pieces per 100 m 12" small end x 25' minimum	1 3	-1 1		R. Frick data
Substrate D50 mm	2 45 362 4096	-1 1 1 -1		Professional judgment
Substrate pool-tail fines %	10 30	1 -1		Professional judgment

(AVE). In addition to operators, each node in the model can also be assigned a weight. For example, 70% of the weight could come from one attribute and 30% from another. In the Franciscan watershed condition model, none of the nodes were weighted.

Reach condition scores were determined in a similar fashion to watershed condition scores. Attribute data values were assigned evaluation scores which were aggregated using operators, and assigned weights to obtain an overall reach condition score (Figure 6).

How to Interpret the Assessment of Watershed Condition

The assessment of watershed condition table in the watershed data summary document presents the evaluation scores from the top down, in an outline format. The indented attributes represent the contributing attributes with their data values and corresponding evaluation scores. At each higher level of the outline, the aggregation of the contributing evaluation scores is displayed, consistent with Figure 5. Reach condition scores for each of the sites that were surveyed in the watershed are presented in the table below with the sites listed from left to right. The tab left of the model output tab in the excel document contains a data dictionary explaining each of the attributes that were evaluated in the model, listed in the same order as on the Watershed Condition table.

RESULTS

Watershed condition scores are the aggregate of all of the road, vegetation, and in-channel attributes collected. These scores range from -0.4 to 1 across the area encompassed by the Plan. In the Franciscan Province, watershed condition scores ranged from -0.05 to 0.41 (Figure 7).

Road condition scores (the aggregate of riparian road density and road crossing frequency) ranged from -1 to 1 across the Plan area, and from -0.1 to 1 in the Franciscan Province (Figure 8). Frequency of road crossings ranged from 0.04 – 1.2 crossings per mi of stream in the province (Figure 9). The distribution of riparian road densities in the Franciscan Province was on the low end of the Plan area distribution (Figure 10). Riparian road density ranged from 0.01 to 0.20 mi. of road per mi. of stream.

Vegetation condition scores, which consist of the evaluation of riparian vegetation and the percentage of the watershed in urban and agricultural land use, ranged from -1 to 1 in both the Franciscan Province and the Plan area (Figure 11). The range of riparian areas in the 6-th fields that contained conifers greater than 20 inches in diameter at breast height was much greater in the Plan area (0-90 %) than in the Franciscan Province (13-56%; Figure 12).

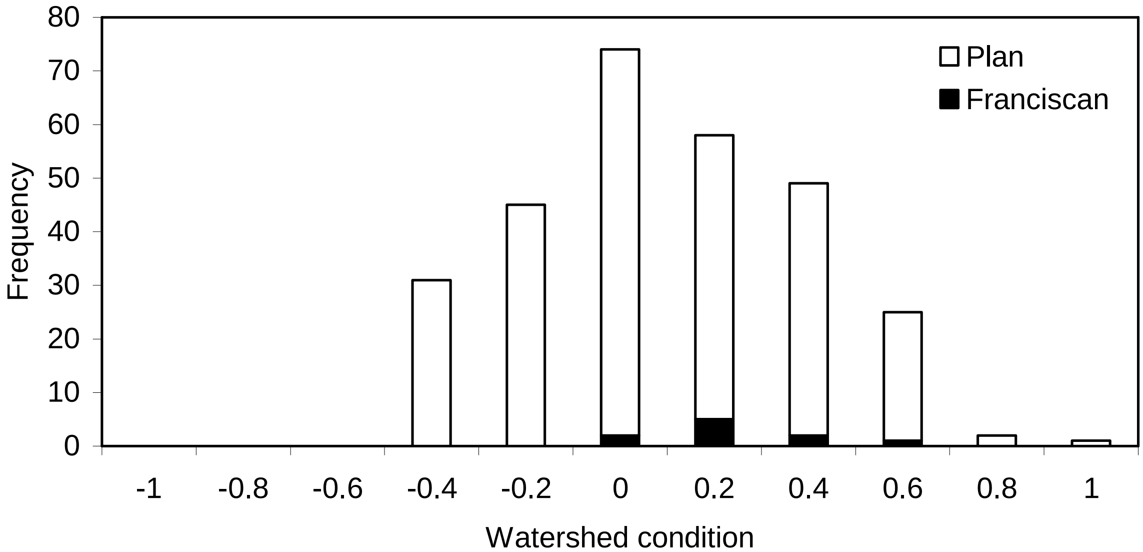


Figure 7. Distribution of watershed condition scores for the Franciscan Province and the Northwest Forest Plan area.

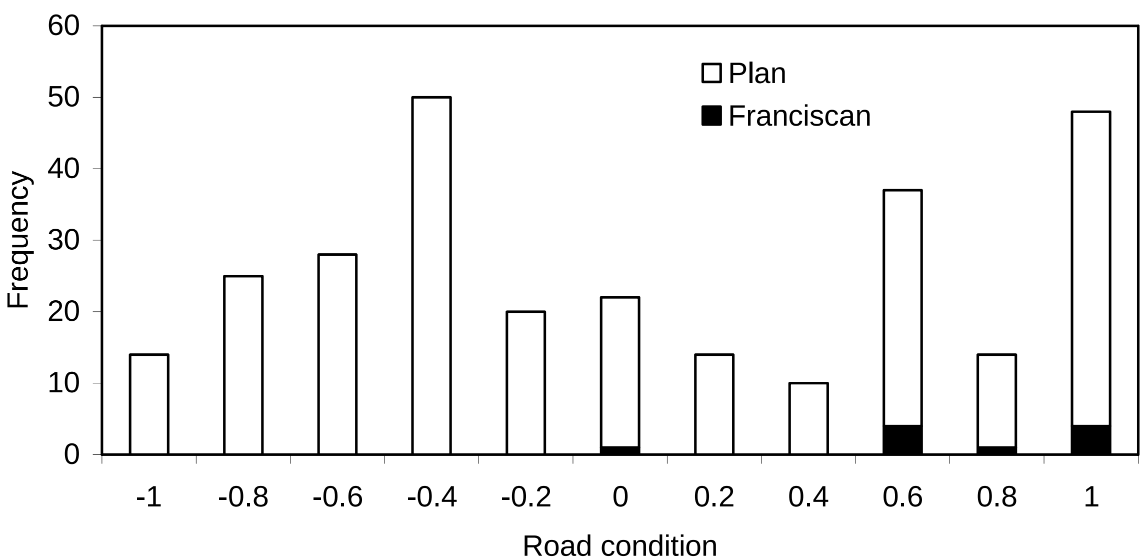


Figure 8. Distribution of road condition scores for the Franciscan Province and the Northwest Forest Plan area.

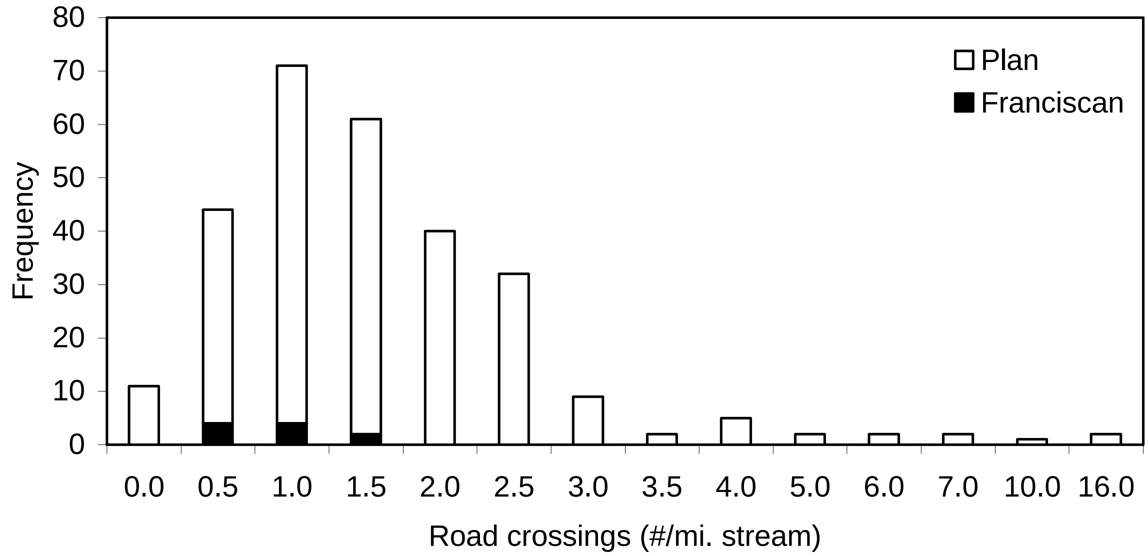


Figure 9. Distribution of road crossing frequencies in 6th-field HUCS in the Franciscan Province and the Northwest Forest Plan area.

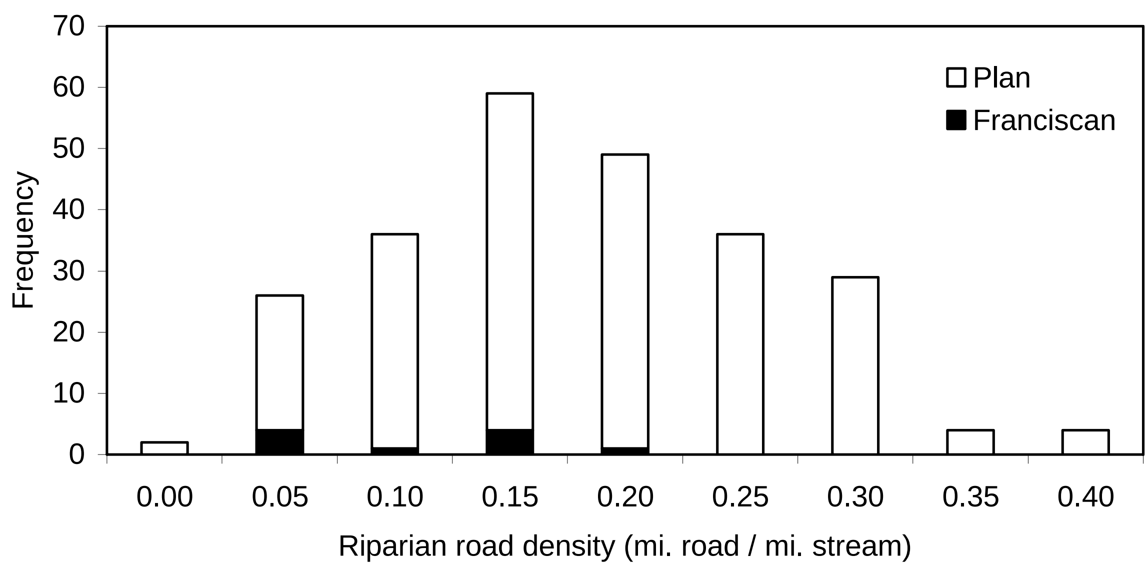


Figure 10. Distribution of riparian road densities in 6th-field HUCS in the Franciscan Province and the Northwest Forest Plan area.

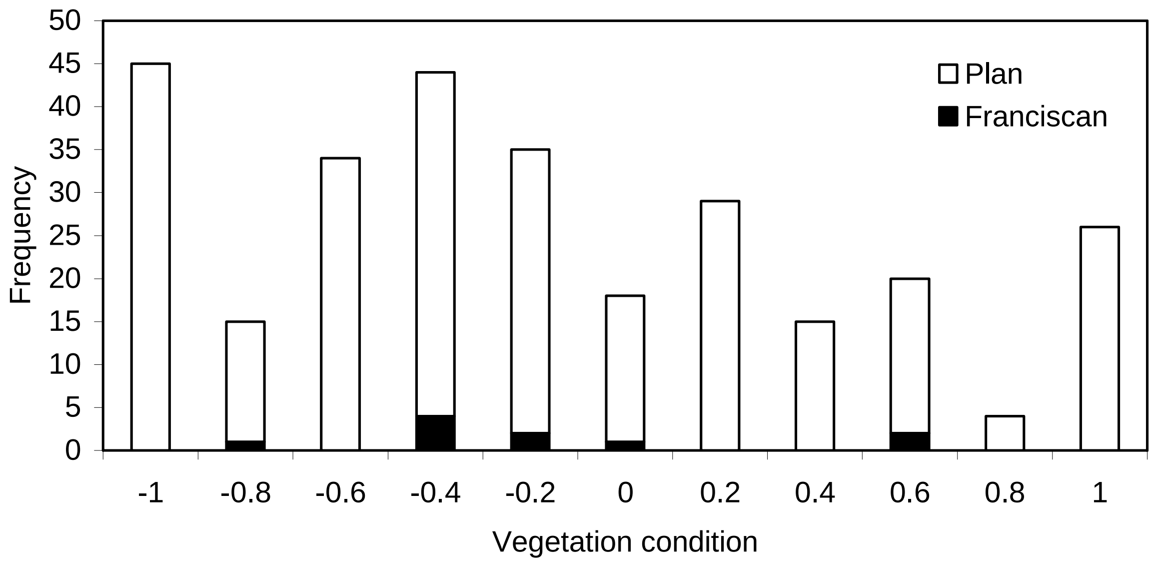


Figure 11. Distribution of vegetation condition scores in 6th-field HUCS in the Franciscan Province and the Northwest Forest Plan area.

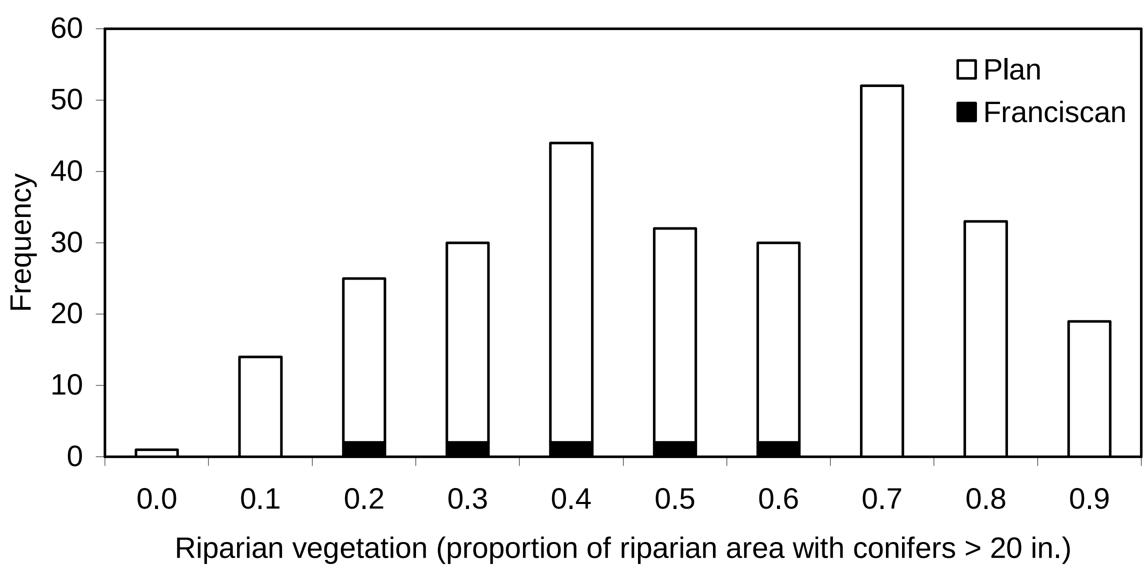


Figure 12. Distribution of riparian vegetation conditions (proportion of the riparian area with conifers greater than 20 inches in diameter at breast height) in 6th-field HUCS in the Franciscan Province and the Northwest Forest Plan area.

CONTACT INFORMATION

For more information regarding the Aquatic and Riparian Effectiveness Monitoring Program, please contact the following personnel or visit our website at: http://www.reo.gov/monitoring/watershed.

Steve Lanigan	Peter Eldred	Kirsten Gallo	Chris Moyer
Module Lead	GIS Coordinator	Aquatic Ecologist	Fish Biologist
333 SW First Ave.	4077 Research Way	4077 Research Way	4077 Research Way
Portland, OR 97208	Corvallis, OR 97333	Corvallis, OR 97333	Corvallis, OR 97333
503.808.2261	541.750.7078	541.750.7021	541.750.7017
slanigan@fs.fed.us	peldred@fs.fed.us	kgallo@fs.fed.us	cmoyer@fs.fed.us

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